In-Situ Gamma-Ray Spectrometry for Radioactivity Analysis Using the Scintillation Detector

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1. Introduction

Scintillation detectors such as NaI(Tl), $LaBr_3$(Ce) and $CeBr_3$ have been widely used for the measurement of field radiation because they can be used at room temperature and operated with relatively compact electronics. Much research has been done on the applications of these detectors in soil and marine environments [1, 2]. In addition, the study on the quantification of radioactivity in soil and marine environments using these detectors might be required to improve the applications of the detectors for in-situ gamma-ray measurement. This paper presents the in-situ gamma-ray spectrometry for radioactivity analysis in soil and marine environments using the scintillation detectors. In the soil, the NaI(Tl), $LaBr_3$(Ce) and $CeBr_3$ detectors were used to evaluate the applicability of in-situ measurement. In the marine environment, the fractional contribution of radionuclide in both seawater and sediment for marine environment presented using the $CeBr_3$.

2. Methods and Materials

The properties of the NaI(Tl), $LaBr_3$(Ce) and $CeBr_3$ used in this study are shown in Table 1.

Table 1. The properties of the NaI(Tl), $LaBr_3$(Ce) and $CeBr_3$

	NaI(Tl)	$LaBr_3$(Ce)	$CeBr_3$
Density ($g \cdot cm^{-3}$)	3.67	5.29	5.10
Decay time (ns)	230	16	18~20
Energy resolution (% at 661.6 keV)	6.0~8.0	2.0~3.5	4.1
Intrinsic radioactivity	-	^{138}La, ^{227}Ac	^{227}Ac

In the soil, to convert net peak count rate in spectrum for any radionuclide to radioactivity, the NaI(Tl), $LaBr_3$(Ce) and $CeBr_3$ detectors were calibrated using semi-empirical method that takes into account the response and angle of the gamma-rays entering the detector [3]. In-situ gamma-ray spectrometry using the calibrated the NaI(Tl), $LaBr_3$(Ce) and $CeBr_3$ detectors was carried out by measuring the natural radionuclides U, Th-series and ^{40}K in an open field (more than 2.5 km^2) with almost flat surface. The results were compared with those of sampling analysis in the laboratory.

In marine environment, peak of any radionuclide obtained by in-situ gamma-ray spectrometry contributes to the corresponding radionuclide in both seawater and sediment. These contribution can be evaluated using the ratio R_T of two in-situ result with relative measurement points h_1 and h_2, and the ratios R_W and R_S of each efficiency in seawater and sediment, as follows :

$$\frac{N_{S_x,h1}}{N_{W_x,h1}} = \frac{\left(1 - {}^{R_T}/_{R_W}\right)}{\left({}^{R_T}/_{R_S} - 1\right)} \; or \; \frac{N_{S_x,h2}}{N_{W_x,h2}} = \frac{\left(1 - {}^{R_W}/_{R_T}\right)}{\left({}^{R_S}/_{R_T} - 1\right)} \quad (1)$$

where $N_{W,h1}$, $N_{S,h1}$, $N_{W,h2}$ and $N_{S,h2}$ mean each count rate of radionuclide in seawater and sediment at detector height h_1 and h_2 from seabed, respectively. To validate this formula, two in-situ measurements with detector height using the $CeBr_3$ were performed by measuring ^{40}K in the marine environment with the tidal phenomenon, and the calibrations for efficiency in seawater and sediment were carried out by the GEANT4 code. The in-situ results were compared with those of seawater and sediment samples analysis.

3. Results and Discussion

In the soil, radioactivity of ^{40}K, ^{208}Tl and ^{214}Bi by in-situ and laboratory measurements agreed well within 5%. The 1460.8 keV (^{40}K), 1764 keV (^{214}Bi) and 2614 keV (^{208}Tl) peaks for the NaI(Tl) and $CeBr_3$, and 583 keV (^{208}Tl), 609 keV (^{214}Bi) and 1460.8 keV (^{40}K) peaks for the $LaBr_3$(Ce) can be analyzed because of the resolution and internal background. When analyzing ^{40}K in the $LaBr_3$(Ce) and $CeBr_3$, internal background peak was subtracted because the ^{40}K peak overlaps with the internal background peak by ^{138}La for the $LaBr_3$(Ce) and ^{227}Ac for the $CeBr_3$, respectively.

In the marine environment, the difference between the in-situ analysis applied by Equation (1) and the sampling analysis showed 3% in seawater and 11% in sediment for the characterization of sediment with depth by the GEANT4 code using the analysis result of sediment samples with depth in the laboratory.

4. Conclusion

We have present the applicability of the NaI(Tl), $LaBr_3$(Ce) and $CeBr_3$ detector in in-situ measurement for soil, and fractional contribution of radionuclide in both seawater and sediment for marine environment using the $CeBr_3$ detector. The conclusion can be drawn these scintillation detectors can be utilized for the quantification evaluations in in-situ gamma-ray spectrometry in both ground and marine environments.

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